Things of science

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TOUCH

Unit No. 327

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TOUCH

This unit of THINGS of science contains a thermometer, Braille alphabet card, nail, wire, cellophane sheet, embossed paper, ruler and polyether foam.

All our knowledge of the world outside ourselves comes to us through our sensory organs, the ears, eyes, nose, tongue and skin, the so-called five senses. Man could not have survived or progressed to his present state without them. They make it possible for us to hear, see, smell, taste and feel.

In general, each of these sensory organs respond only to particular types of stimuli. We see with our eyes and hear with our ears, and no matter how we may try, we cannot see with our ears nor hear with our eyes. Our tongue tells us whether a food is bitter or sweet and we smell the fragrance of a flower with our nose.

The skin, however, responds to several types of stimuli, heat, cold, pain, pressure and touch.

All of the senses mentioned above are of utmost importance to our well being. But in order for us to respond to the various types of stimuli in our environment, we must have a sensory system that is working properly.

The sensory system is composed of

three main parts, the receptors, the nerve pathways and the brain. Sensations or "feelings" are the result of integrated activity in all of these. However, we shall devote our attention here to the first step in the process, i.e., receptor stimulation.

The receptors are the nerve endings that react to various stimuli. The impulses from these stimuli make their way along the nerve pathways which connect with small cells called neurons (located on the spinal cord), and these small cells in turn send the messages along their own fibers to higher centers of the brain.

When the brain receives the messages, it interprets them as various types of sensation, such as sound, taste or touch, depending upon which receptors were stimulated.

The receptors themselves are classified into three groups—the exteroceptors, which receive stimuli originating outside the body, the proprioceptors which respond to muscle stimuli and interoceptors that receive messages from the internal organs of the body.

In this unit we are concerned primarily with a particular group of exteroceptors—those that are located in the skin.

The skin receptors are usually grouped together and referred to as cutaneous re-

ceptors.

We commonly talk of feeling hot or cold, feeling a touch, or feeling pain or pressure.

The experiments in this unit will show you how these feelings differ and yet how in some ways they are related to each other.

First examine the materials in your unit.

BRAILLE CARD—Shows letters and alphabet in Braille.

THERMOMETER—In degrees Fahrenheit.

RULER—Containing both inches and centimeters.

NAIL

WIRE

CELLOPHANE SHEET

EMBOSSED PAPER

POLYETHER FOAM

THE SKIN

The skin is the largest organ system of the body. It serves as man's protection against his environment and helps him adjust to it as well.

The skin consists of two layers, an outer layer called the epidermis and an inner layer, the dermis.

Experiment 1. Observe your skin and note that it is smooth in some places,

wrinkled in others, hairy on the arms and hairless on the palms.

The skin you see is the outer portion of the epidermis and is composed of dead cells in which neither nerves nor blood vessels are present. Just beneath this layer is the living portion of the epidermis which continually replenishes the outer layer with dead cells as the cells are worn off from the surface. The dead outer layer protects all the living tissue beneath from bacterial invasion as well as any penetration of dust and dirt into the body.

The nails and hair originate from the epidermis and are also composed of dead cells.

The epidermis is thicker in some parts of the skin than in others, as on the palms and soles, and tends to thicken wherever there is continual rubbing or pressure. For example, callouses on the palm from working with tools are due to thickening of the epidermis.

Experiment 2. You can demonstrate that the top layer of epidermis is made of dead cells by pricking the surface of your palm with a pin. Do this carefully and you will neither feel pain nor draw blood.

Beneath the germinating layer of the epidermis is the dermis, a layer of white

elastic tissue filled with blood vessels and millions of nerve endings. The roots of the hair in the hairy parts of the skin penetrate deep into the dermis.

Experiment 3. Look at the palm of your hands carefully and at the tips of your fingers. Can you see the parallel rows of lines? Those on the tips of your fingers serve as your identification since each individual has characteristic fingerprints unlike anyone else's.

Observe them under a magnifying glass. These raised lines are caused by the structure of the upper part of the dermis which contains many tiny papillae arranged in parallel rows.

There are at least five types of receptors in the skin, each with a different structure, which receive stimuli for cold, warmth, pain, touch and pressure.

A cross section of the skin observed under a microscope reveals that some of the receptors are branched free nerve endings while others are disk-shaped or encased in a thin layer of cells. The various receptors are named after the persons who discovered them (see diagram in Fig. 1).

Each of these types respond to certain kinds of stimuli more easily than to others, and are found with different frequency in different patches of skin.

Experiment 4. Take your nail and holding it loosely, lightly draw its point along the skin on the inside of your forearm. What sensations do you feel? Can you distinguish feelings of cold, tickling and light touch? Repeat along several parallel paths. Note that the different sensations do not necessarily occur alongside each other.

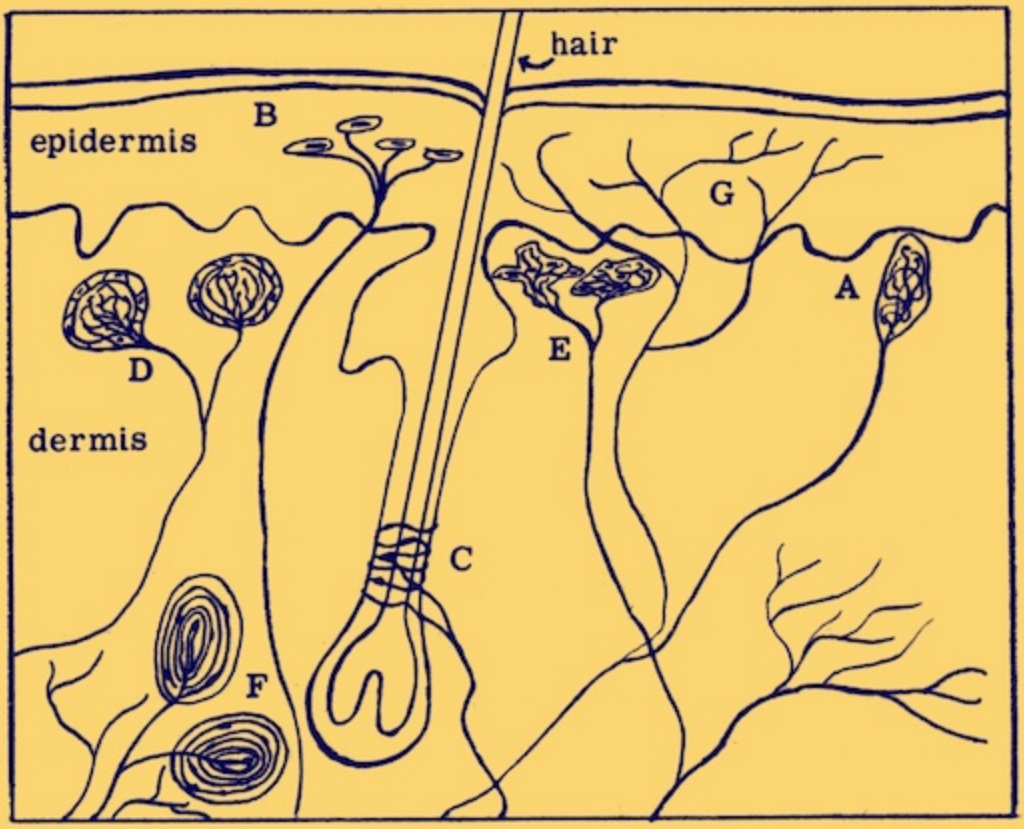


Fig. 1

Legend for Fig. 1:

A. Meissner's corpuscles (touch)
B. Merkel's disks (touch)
C. Nerve endings encircling hair follicles (touch)
D. Krause's end bulbs (cold).

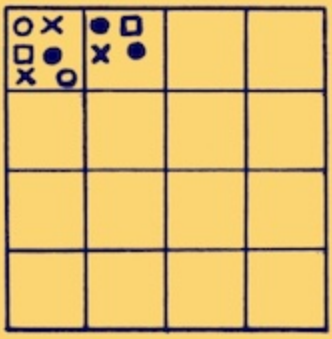
E. Ruffini's end organs (warmth)
F. Pacinian corpuscles (pressure)
G. Free nerve endings (pain) (and also temperature, pressure and touch)

Experiment 5. To show the unequal distribution of the receptors map a small area on the back of your hand.

Draw a two-centimeter square area on the back of your hand with a soft pencil or washable ink. Next draw lines across the area at half-centimeter intervals, horizontally and vertically to make 16 equal squares (Fig. 2).

Now draw a similar chart on a piece of paper so that you can note down your results.

Touch the skin, or better have someone else do this for you while you are blindfolded, within each ½-centimeter square with the point of the nail. Do this lightly without pressure noting the points where you feel touch. Since the nail will feel cold you can also map the cold spots.



touch—o
cold—x
warmth—□
pain—●

Fig. 2

Mark each sensation with a symbol in the corresponding spot on your diagram (Fig. 2) or make dots with different colored inks to indicate the types of sensations.

To find the warm spots, heat the point of the nail in very hot water and then map as before. To plot the pain spots, use one end of the wire in your unit or a pin.

Which spots are the most numerous?

The sensation of pain and touch result from the deformation of the nerve endings by the stimulus. Since the nerve endings are flexible, slight pressure on the skin will cause them to be easily displaced.

Experiment 6. Map an area on the inside of your forearm. Compare the distribution of the sensory spots with that on the back of your hand.

Experiment 7. Map areas on the hands and arms of several friends and compare them.

Although we can map the receptors in this way, the skin senses are very complex and exactly how we feel the different touch sensations is not completely clear and much research still needs to be done in this field.

Let us examine each of these senses separately.

Experiment 8. Have someone blindfold you and then walk around in a darkened room guiding yourself by touch. Can you? This is an example of one of the main purposes of the sense of touch—to guide one without the use of other sensory organs.

Although in the modern world man does not often have to feel his way in complete darkness, the tactile sense was most important to him before he learned to light his way with a torch at night.

The receptors for touch are scattered all over the body, but they are not evenly distributed, being more numerous in some areas than others.

Experiment 9. Cut a very narrow strip, as fine as a thread, lengthwise from the cellophane sheet in your unit. Save the rest carefully for a later experiment.

Lightly run this strip along the outside of your forearm. Do you feel it? You will perceive a sensation of light touch, or perhaps a tickling sensation. Draw the strip across your palm and fingertips. Can you feel it in either location? Now draw it across your chin and forehead.

Note that the hairy parts of your skin are very sensitive to light touch. The

movement created in the hair, no matter how slight, stimulates the nerve endings around the follicles.

In the palm and fingers where there are no hairs, the skin is not as sensitive to feathery light touch.

But these two areas, as well as the soles and lips, are closely packed with Meissner's corpuscles, more so than in any other parts of the skin and are extremely sensitive to direct touch.

Experiment 10. With the nail touch the palm of your hand in close succession along a straight line. Note that while on the back of your hand you may have found spots with no touch sensation, on your palm you sense touch with each contact.

Experiment 11. Smoothness and roughness are detected by the tactile sense. Place the cellophane sheet and the embossed paper flat on a table in front of you. Now very lightly touch the surface of each with your index finger. Is the sensation the same in both cases?

Now while touching the cellophane with the same lightness move your finger across it. Does it feel smooth? Repeat with the embossed paper. Can you feel the unevenness of the paper?

By exposing the skin to different stim-

uli in succession, you can tell the texture of a substance.

Stickiness is also noted in the same way. How would you demonstrate this?

BRAILLE

This sensitivity of the fingertips to touch is of especial usefulness to the blind. They can learn much about an object by feeling it—how large it is, whether it is soft or rough. But most important of all they can read by running their fingers over the raised dots of the Braille alphabet. Movement of different tactile receptors over the same surface is the key to this ability.

Experiment 12. Examine your card showing the Braille alphabet and numbers.

These cards were contributed for this unit by the American Foundation for the Blind, New York, N. Y.

This method of reading by raised dots is based on a system devised by a French musician, Louis Braille, more than 100 years ago. The system employs up to six dots arranged in two vertical columns, in various positions and combinations to represent the different letters of the alphabet and the digits from 0 to 9.

Move your fingers over the dots. Note how distinctly you can feel them. With

a little practice you will soon be able to read many of the letters in Braille, but to be a proficient reader by this system a person needs years of practice.

The skin on the tips of the index fingers of persons who read Braille regularly becomes thickened. However, this does not hamper their reading ability. In fact, it is believed to be helpful, since with less sensitive fingertips fewer adjacent receptors are stimulated, and the stimuli are better localized.

Experiment 13. Place your hand lightly on top of one of the letters of the Braille alphabet. Can you distinguish the number and position of the spots?

Measure the distance between the dots. The fingertips are so sensitive that they can sense two points that are only about one-millimeter apart. Place your finger on the letter h. Can you tell that there are three dots? Move your finger across the letter. Is it easier now to sense them and their positions? This is an example of the principle you observed in Experiment 11.

A reader of Braille distinguishes position, distance and number of dots in each of the letters as well as the symbols meaning periods, commas, capital letters and other designations such as contrac-

tions of commonly used words and phrases, indicating that positions in space can be localized through the sense of touch. The space between letters in a Braille word has been standardized to ¼ inch.

It is popularly believed that the blind, by the constant use of their sense of touch, develop it to a degree far beyond the capabilities of those who can see. But research suggests that this is not so. The sensitivity of the blind will not exceed the individual's natural endowment, but a blind person by practice becomes more fluent. In brief, the brain becomes more able to correctly interpret the incoming signals from the tactile receptors.

TWO-POINT TOUCH

Experiment 14. Hold your wire which is folded in two like tweezers so that the two ends are about a quarter of an inch apart.

Touch the two points to your forearm at the same time with equal pressure. Do you feel one or two touch sensations? Separate the two points a little more and then touch your skin again. Repeat the experiment gradually increasing the distance between the wires until you definitely feel two touch sensations. When

this happens, measure the distance between them. In most people it will be about 1½ inches.

Repeat on your fingertips. Are they more sensitive? Can you distinguish two points when the distance between them is only about one millimeter?

This difference in the ability to distinguish two stimuli when applied to different parts of the skin arises in part because of the different number of receptors and nerve fibers in the various areas. The greater the number of fibers coming from an area of skin, each carrying its own individual message to the brain, the easier it becomes to distinguish between closely spaced tactile stimuli.

Experiment 15. Repeat the experiment on other parts of your skin from head to toe. Each area has its own threshold for feeling two points.

Experiment 16. As you have observed, when two stimuli are a very short distance apart, they add their effects into one common sensation. But if one stimulus is greater than the other let us see what happens.

Place the two points of the wire on your forearm at a distance where you will feel a single touch. Now press one a little

harder. Where do you feel the sensation?

Now spread the wires to a point where you can feel two points. Then press one harder than the other. Where do you feel the stimulus this time?

When one cutaneous stimulus is greater than another, which is nearby, the nerve fibers coming from the first region of skin send impulses more rapidly to the brain (as many as 300 per second) and the stimulus is felt as more intense; in addition, the messages coming from the weakly stimulated point are inhibited, so that they fail to reach the higher centers of the brain.

LOCALIZATION

Experiment 17. Have someone lightly touch your arm, back or face while you are blindfolded. Can you locate the exact spot of the touch? Easily.

During the early years of your development you learned to localize the various skin sensations, an ability essential for adjusting to your environment.

Experiment 18. Ask a person to write a number or letter of the alphabet in your palm while your eyes are closed. You will be able to tell him what the letter is in most cases.

Experiment 19. But sometimes your

well-learned lessons will fool you.

Draw the nail in your unit back and forth between the tips of the index and middle fingers in your left hand.

Then cross the two fingers and rub the nail between the crossed fingers. Do you feel two nails? What causes this illusion?

You have become accustomed to believe through the years that in order to stimulate the left side of the middle finger and the right side of the index finger in your left hand at the same time two separate stimuli are necessary, one for each side, and the impulses from these two areas go to different centers in the brain.

Therefore, although the two fingers are exposed to the same stimulus, at the same time, the brain on receiving the messages automatically interprets them as coming from two independent objects.

SPATIAL SENSATION

Experiment 20. Lightly run the edge of the embossed paper across the hairs on your arm without touching your skin. As you do this it seems as if the hair itself is feeling the paper. But actually the nerves around the hair follicles are stimulated by the movement of the hair.

Thus, the sense of touch appears to be extended beyond your body and localized.

The hair itself as you know is dead and cannot feel.

A cat uses his whiskers in the same way to direct him as he makes his way down a narrow passage.

Experiment 21. Straighten out your wire and with your eyes closed hold one end allowing the other end to pass across the surface of an object. Can you feel the object? Can you tell its approximate location and whether it is smooth or rough?

Although you are actually receiving the sensations through your fingers, and from your muscles and joints because of the movement of the arm, you project the feeling to the tip of the wire. This is how a blind person feels his way with a cane. Thus, the sensation of touch plays an important part in your ability to localize objects in space.

TEMPERATURE

Very little is known about the temperature sense. It was generally believed that Krause's end bulbs feel cold while Ruffini's end organs sense warmth, but new studies suggest that free nerve endings are also sensitive to temperature. In general, certain receptors are stimulated by temperatures that are lower than the body temperature (98.6°F), while others are

stimulated by temperatures that are higher than the body temperature.

Experiment 22. Let us map an area of the skin on the back of the hand for cold and warm spots only Place the nail in ice water and locate the cold spots, noting them down on a similar area drawn on a piece of paper.

Then place your nail in hot tap water and map the warm spots.

Which are more numerous? There are more cold than warm receptors in the entire skin, but this may not be true of the particular area you may choose to map.

Experiment 23. Try to stimulate a cold spot with a heated point and a warm spot with a cold stimulus. Can you? You will find that the cold and warm spots are in general distinct.

Experiment 24. From experience you have learned that ice feels cold and fire feels hot. However, can you always tell hot from cold?

Fill three bowls with water—one with cold, another with warm and a third with hot water.

Place your right hand in the cold water and left hand in the hot water for a few minutes. Then immerse both hands in the warm water at the same time.

Note your sensations. This experiment demonstrates that the temperature receptors are sensitive to *changes* in temperature rather than to hot or cold as such.

When you placed your cold right hand into the warm water, it felt warm because the heat from the warm water flowed into your hand making it warmer and stimulating the heat receptors. When the hot left hand was placed in the warm water, heat from the hand flowed into the water making the skin cooler causing the sensory organs for cold to be stimulated and the hand to feel cold.

Can you think of other ways to demonstrate this phenomenon?

Experiment 25. Place your nail and the embossed paper on the table and find their temperatures with your thermometer by placing the bulb against each. Are their temperatures the same? They should both be at room temperature. Place the nail against your face. Do the same with the cellophane. Why does the nail feel so much colder than the cellophane although both are the same temperature?

The nail, made of iron, is a conductor of heat and draws warmth from your body, thus stimulating the cold receptors. But cellophane is a non-conductor and if kept against the skin produces a feeling

of warmth.

(The thermometer in your unit has a cardboard backing which will soften if placed in water. Therefore, before using the thermometer in the following experiments cut off the backing at the bottom to about —30°.)

Experiment 26. Fill a bowl with water of about 110°F Immerse your fingers in the water and then immerse your elbow. Does the water feel hotter to the fingers or to the elbow?

A baby's skin is very sensitive to temperature and the water for a baby's bath is usually lukewarm, or about 90° to 98°F. Many mothers use their elbow rather than their hand to test the temperature of the water. Why?

However, as you know, we cannot always depend upon the accuracy of our senses so the scientific approach would be to use the thermometer.

Experiment 27. The cold and warmth receptors are very sensitive to directional changes in temperature. Check the sensitivity of yours.

Fill two bowls with water which vary in temperature only one degree. Place your hand in the cooler water and then in the warmer. Can you detect a difference in temperature?

Remember to allow your hands to return to their normal temperature after each experiment or your results will be misleading.

Repeat the experiment, but this time place your hand in the warmer water first.

Try various degrees of changes from warm to cold and cold to warm. Are you more sensitive to changes of increasing or decreasing temperatures?

You have probably noticed that when your hands are placed in *very* hot water you feel sensations of both hot and cold at the same time. In very hot water the cold receptors are also stimulated, but the brain interprets any stimulation of these receptors as cold. A similar stimulation of the warm receptors occurs when the hands are exposed to freezing cold, causing them to feel hot as well as cold.

PRESSURE

Deep in the dermis are the pressure receptors, (1) the Pacinian corpuscles, which are oval or round in shape and composed of thin layers of tissue like an onion, and (2) free nerve endings.

Experiment 28. Press the head of your nail down on your forearm, lightly at first and then gradually increase the pressure. First you will feel a sensation of

touch only, but as you press harder the Pacinian corpuscles and more superficial free nerve endings are deformed and you feel pressure or deep touch, as this sensation is also called.

Press the nail down more strongly. Do you feel pain? The sensation of pain results from the stimulation of other free nerve endings located perhaps deeper in the skin than the pressure sensory organs.

The pressure sense is very important in letting us know about our environment. It is this sense that tells us whether a dress is too tight or a collar too snug.

Pressure receptors also tell us whether an object is heavy or light. We understand from experience that a heavy object, due to the force of gravity, puts a greater pressure on a greater number of receptors than do light objects. The brain interprets this sensation as weight. In such pressure sensations, muscle sense or the proprioceptors are also involved.

Experiment 29. Feel your polyether foam noting its softness. Feel the hardness of the nail. How do we sense softness and hardness?

Place the two on the table and touch each very lightly with a finger. Can you tell which is hard or soft by light touch?

Push down on the foam and then on

the nail. You can sense at once which is soft and which is hard. One gives way to pressure and the other resists it. More pressure receptors are stimulated by a hard object, and also more intensely, than by a soft one and our brain on receiving these impulses tells us that the greater the resistance an object exerts to pressure, the harder it is.

Thus, to feel softness and hardness we employ both tactile and pressure sense.

Experiment 30. Hold any solid object in your hand and note which of the two sensations, touch and pressure, you feel. Which do you feel when you place your hand in water? Which from the air in a closed room?

With a solid you feel both touch and pressure; with water touch only, and with gas neither pressure nor touch.

Thus we can define a solid, liquid and gas by relating them to our skin senses.

PAIN

The pain receptors are the most numerous and most widely distributed of the skin senses. Their basic function is to protect the body by providing information of dangers by means of their responses.

The sensory organ of pain is composed of free nerve endings that branch like

limb of a tree, and are usually found in the deeper layers of the skin, in the joints, in muscles, in the cornea of the eye, pulp of the teeth, the eardrum and internal organs of the body.

The perception of pain is a very complex reaction involving not only the properties of the stimulus, but also the state of the brain. It depends more upon the past and present activity of the brain than any of the other senses. Fear and anxiety as well as cultural background may influence the perception of pain.

The intensity of the pain a person feels, therefore, is not necessarily proportional to the intensity of the stimulus or to the extent of injury. Thus, a soldier in battle may be severely wounded and feel no pain, while an athlete may be unaware of broken bones during intense play. But these same persons may exaggerate relatively minor pain sensations suffered under a dentist's drill or hypodermic needle.

The pain threshold varies, therefore from individual to individual and with the circumstances under which the stimulus is presented.

However, we are ordinarily made aware of dangers by the pain we feel when we pinch a finger in a door, burn or bruise ourselves. Without such an awareness we

would unknowingly suffer numerous injuries.

Some persons in whom the pain sense is missing may be subject to a variety of accidents without feeling any pain, and they must learn to protect themselves by constant watchfulness.

Experiment 31. Pain may be due to mechanical, thermal or chemical stimulation.

Gently touch your skin with a sharp pin. The slightest touch causes a pricking sensation. This is an example of mechanical stimulation. The sensation is caused by displacement of the nerve endings.

Pain resulting from contact with a hot object is caused by thermal stimulation, while a burning sensation due to a drop of concentrated acid on the skin gives pain by chemical stimulation. In each case, however, the same class of receptors is stimulated, perhaps by a common, but unknown mechanism which is affected by the seemingly different stimuli.

Experiment 32. Some persons feel a double pain response from a pin prick or other injury depending upon the pathways taken by the pain impulses which travel faster along some routes than others. The brain then receives two consecutive messages from the same area of skin.

Do you detect two stimuli when you prick yourself?

Experiment 33. Map the pain spots on your forehead and forearm. Are there very many? Pain receptors are numerous on the forehead and lower arm. There are about 200 pain spots per square centimeter on the forearm.

Our body adjusts more easily to other sensory stimuli than to those producing pain. Why do you think this is so?

When we put our clothing on, we feel it as it is placed in contact with our skin, but once clothed we are no longer aware of it.

Water may feel cold when we jump into it for a swim, but soon our body becomes used to its coolness.

These adjustments are made by both our receptors and our brain, and are very necessary. Otherwise we would be reacting constantly to thousands of miscellaneous stimuli, leaving us no time to think about more important things.

A tight shoe, on the other hand, is difficult to ignore, and the pain of an aching tooth even more so. Pain keeps nagging at us until it is appeased.

These experiments illustrate some aspects of cutaneous sensation. However, many of the nervous mechanisms involved are poorly understood, and researchers still seek answers to numerous puzzling questions.

For those of you who may wish to read further on the subject, here are a few references.

Elementary physiology textbooks.

Biology textbooks.

Fundamentals of Neurology, Ernest Gardner, W. B. Saunders Co., Philadelphia, Pa.

Sensory Inhibition, Georg von Békésy, Princeton University Press, Princeton, N. J.

The Human Nervous System, Charles R. Noback, McGraw-Hill Book Co., New York.

Appreciation is expressed to Dr. Donald R. Humphrey, National Institutes of Health, Bethesda, Md., for reviewing this booklet.

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